PVT Properties of Oil, Gas, and Water
Add-in for Microsoft Excel

FOREWORD

The physical properties of petroleum fluids are required for most petroleum engineering calculations. During the 1980's an "application module" known as the Petroleum Fluids Pack was developed and marketed by Hewlett Packard for use in their HP-41 series programmable hand-held calculators. This software ROM utilized common empirical relationships to estimate PVT properties for oil, gas, and water. HP developed this set of programs with the assistance of Mr. D. N. Meehan (Champlin Petroleum Company) and Dr. H. J. Ramey (Stanford University). While the module and calculator that it required have not been available for many years, they remain popular with many petroleum engineers.

With the growth and adoption of desktop computers and spreadsheets for petroleum engineering calculations, a need to directly estimate PVT properties using spreadsheet functions similar to the original HP Petroleum Fluids Pack exists. This Microsoft Excel spreadsheet add-in was an effort to directly duplicate many of the programs of Meehan and Ramey in the original Petroleum Fluids Pack into a form readily usable in Excel. The references listed as the basis for each fluid property correlation are reproduced directly from the original HP Petroleum Fluids Pack operating manual.

While particularly useful in spreadsheets, estimates of physical properties using empirical correlations should always be considered approximate. Actual laboratory measurements should be utilized when available. Of particular concern is the use of an empirical correlation outside of its stated range of validity. While nothing prevents the user from using these Excel add-ins outside the stated valid ranges, it should be recognized that serious errors are possible. Please carefully note the "ranges of validity" for each listed function that are reproduced from the original HP Petroleum Fluids Pack operating manual.

INSTALLATION

Installation of Excel add-ins is process that only requires only a few simple steps. Once installed, the add-in will automatically be available whenever Excel is started.

1. The file PVTProps.XLA must first be downloaded and saved locally on the computer. The creation of an appropriate subdirectory (such as "Petroleum Engineering Excel Add-ins") may be desirable for storing the add-in in a safe but unobtrusive location.

2. Start Excel in the normal manner.

3. Choose the Tools ⇒ Add-Ins command.

4. From the Add-ins dialog box, click on browse and locate the PVTProps.XLA file that you saved in step 1.

Once installed, the fluid property functions can be accessed in any Excel formula in the same manner as other built-in numeric functions (i.e. sin, ln, etc.). The spreadsheet named "Example PVTProps.XLS" can be opened in Excel to view examples of the use of the functions. The basic code may also be inspected and modified if desired in the actual add-in file "PVTProps.XLA."

FUNCTION LIST

Bubble Point Pressure (psia)	BP(API, GOR, T, SG, SepT, SepP)
Critical Pressure for Miscellaneous Gases (psia)	Pcm(SG, N2, CO2, H2S)
Critical Temperature for Miscellaneous Gases (ºR)	Tcm(SG, N2, CO2, H2S)
Gas Compressibility (psi^{-1})	Cg(P, T, SG, N2, CO2, H2S)
Gas Pressure from P/Z (psi) for Misc. Gases	Pressure(PoverZ, T, SG, N2, CO2, H2S)
Gas Pseudopressure (psi^2/centipoise)	mp(P, T, SG, N2, CO2, H2S)
Gas Viscosity (centipoise)	Ug(P, T, SG, N2, CO2, H2S)
Gas-Water Ratio (SCF/STBW)	RSwat(T, P, Salt)
Gas Z Factor	Z(P, T, SG, N2, CO2, H2S)
Live Oil Viscosity (centipoise)	Uo(API, P, T, GOR, Pbp)
Oil Compressibility (psi^{-1})	Coabp(API, GOR, P, T, SG, SepT, SepP)
Oil Form. Volume Fact. (rb/STBO)	Bo(P, Pbp, API, GOR, T, SG, SepT, SepP)
Solution Gas-Oil Ratio (SCF/STBO)	RS(P, API, T, SG, SepT, SepP)
Water Compressibility (gas saturated) (psi^{-1})	Cw(T, P, Rsw, Salt)
Water Formation Volume Factor (gas saturated) (rb/STBW)	Bw(T, P, Salt)
Water Viscosity (gas saturated) (centipoise)	Uw(T, P, Salt)

NOMENCLATURE

API	Oil gravity - ºAPI
CO2	Mole percent carbon dioxide
GOR	Solution gas-oil ratio – SCF/STBO
H2S	Mole percent hydrogen sulfide
N2	Mole percent nitrogen
P	Pressure - psia
Pbp	Bubble point pressure – psia
PoverZ	Gas pressure / Z Factor - psia
Salt	Weight % salt
SepP	Separator pressure - psia
SepT	Separator temperature - ºF
SG	Gas specific gravity relative to air
T	Temperature ºF

FUNCTION DETAIL

Bubble Point Pressure (psia) **BP(API, GOR, T, SG, SepT, SepP)**

Ranges of validity: $76 < SepT < 150^oF$
$30 < SepP < 535$ psia
For $15 < {}^oAPI \leq 30$
$0.511 < SG < 1.351$
For $30 < {}^oAPI \leq 59.5$
$0.530 < SG < 1.259$

Reference:

Vasquez, M., and Beggs, H. D., "Correlations for Fluid Physical Property Predictions," *Journal of Petroleum Technology*, June 1980, pp. 968-970.

Critical Pressure for Miscellaneous Gases (psia) **Pcm(SG, N2, CO2, H2S)**
Critical Temperature for Miscellaneous Gases (^oR) **Tcm(SG, N2, CO2, H2S)**

Ranges of validity: $0 \leq \%N2 < 100$
$0 \leq \%CO2 < 100$
$0 \leq \%H2S < 100$
$0 \leq \%N2 + \%CO2 + \%H2S < 100$
$0 \leq \%CO2 + \%H2S < 80$

Reference:

Standing, M. B., *Volumetric and Phase Behavior of Oil Field Hydrocarbon Systems*, 1977, pp. 26, 122.

Gas Compressibility (psi^{-1}) **Cg(P, T, SG, N2, CO2, H2S)**

Ranges of validity: same as Z factor.

References:

Meehan, D. N., and Lyons, W. K., "Calculations Programmable for Gas Compressibility," *Oil and Gas Journal*, Oct. 8, 1979, pp.74-78.

Trube, A. S., "Compressibility of Natural Gases," *Trans. AIME*, 1957, p. 335.

Gas Pressure from P/Z (psi) for Misc. Gases **Pressure(PoverZ, T, SG, N2, CO2, H2S)**

Ranges of validity: same as Z factor

Note: this quantity is useful in gas material balance calculations.

Gas Pseudopressure (psi^2/centipoise) **mp(P, T, SG, N2, CO2, H2S)**

Ranges of validity: same as Z factor and gas viscosity.
Note: This function uses the Z factor and gas viscosity correlations to numerically integrate the quantity $2P/\mu Z$ from a base of zero to the pressure P.

Gas Viscosity (centipoise) **Ug(P, T, SG, N2, CO2, H2S)**

Ranges of validity: $40 < T < 460^oF$
$14.7 < P < 10{,}000$ psi

References:

Lee, A. L., Gonzalez, M. H., and Eakin, B. E., "The Viscosity of Natural Gases," *Journal of Petroleum Technology*, August, 1966, pp. 997-1000.

Gonzalez, M. H., and Lee, A. L., "Graphical Viscosity Correlation for Hydrocarbons," *AIChE Journal*, March, 1968, pp. 242-244.

Gas-Water Ratio (SCF/STBW) **RSwat(T, P, Salt)**

Ranges of validity: $90 < T < 250^oF$
$500 < P < 5{,}000$ psia
$0 \leq$ Salt $< 3\%$ by weight

References:

Craft, B. C. and Hawkins, M. F., *Applied Petroleum Reservoir Engineering*, Prentice-Hall, 1959, p.130.

Ramey, H. J., Stanford University, unpublished correspondence.

Gas Z Factor **Z(P, T, SG, N2, CO2, H2S)**

Ranges of validity: $1.05 < TR < 3.0$, where $TR \equiv T/Tcm$
$0 < PR < 30$, where $PR \equiv P/Pcm$

Note: Other ranges of validity apply for the critical temperature and pressure that are estimated from the functions Tcm and Pcm listed below.

References:

Dranchuk, P. M., Purvis, R. A., and Robinson, D. B., "Computer Calculations of Natural Gas Compressibility Factors Using the Standing and Katz Correlation," *Institute of Petroleum Technical Series*, No. IP 74-008,1974.

Takacs, G., "Comparisons Made for Computer Z-Factor Calculations," *Oil and Gas Journal*, Dec. 20, 1976, pp. 64-66.

Live Oil Viscosity (centipoise) **Uo(API, P, T, GOR, Pbp)**

Ranges of validity: $76 < T < 295^oF$
$16 < {}^oAPI \leq 58$
For $P > Pbp$
$111 < P < 9{,}485$ psia
For $P < Pbp$
$20 < GOR < 2{,}070$ SCF/Bbl
$14.7 < P < 5{,}265$ psia

References:

Beggs, H. D., Robinson, J. R., "Estimating the Viscosity of Crude Oil Systems," JPT Forum, September, 1975, pp. 1140-1141.

Vasquez, M., and Beggs, H. D., "Correlations for Fluid Physical Property Predictions," *Journal of Petroleum Technology*, June 1980, pp. 968-970.

Oil Compressibility (psi^{-1}) **Coabp(API, GOR, P, T, SG, SepT, SepP)**

Ranges of validity: P > bubble point pressure
$111 < P < 9{,}485$ psia
$76 < SepT < 150^oF$
$30 < SepP < 535$ psia
$15.3 < {}^oAPI \leq 59.5$
$0.511 < SG < 1.351$

References:

Ramey, H. J., "Rapid Methods for Estimating Reservoir Compressibilites," *Journal of Petroleum Technology*, April, 1964, pp. 447-454.

Vasquez, M., and Beggs, H. D., "Correlations for Fluid Physical Property Predictions," *Journal of Petroleum Technology*, June 1980, pp. 968-970.

Oil Form. Volume Fact. (rb/STBO) **Bo(P, Pbp, API, GOR, T, SG, SepT, SepP)**

Ranges of validity: $76 < SepT < 150^oF$
$30 < SepP < 535$ psia
$15.3 < {}^oAPI \leq 59.5$
Above bubble point
$0.511 < SG < 1.351$
$111 < P < 9{,}485$ psia

Below Bubble Point

For 15.3 < °API ≤ 30

0.511 < SG < 1.351

14.7 < P < 4,542 psia

For 30 < °API ≤ 59.5

0.530 < SG < 1.259

14.7 < P < 6,025 psia

References:

Ramey, H. J., "Rapid Methods of Estimating Reservoir Compressibilities," Journal of Petroleum Technology, April, 1964, pp. 447-454.

Vasquez, M., and Beggs, H. D., "Correlations for Fluid Physical Property Predictions," *Journal of Petroleum Technology*, June 1980, pp. 968-970.

Solution Gas-Oil Ratio (SCF/STBO) **RS(P, API, T, SG, SepT, SepP)**

Ranges of validity: 76 < SepT < 150°F

30 < SepP < 535 psia

For 15 < °API ≤ 30

0.511 < SG < 1.351

14.7 < P < 4,542 psia

For 30 < °API ≤ 59.5

0.530 < SG < 1.259

14.7 < P < 6,025 psia

Reference:

Vasquez, M., and Beggs, H. D., "Correlations for Fluid Physical Property Predictions," *Journal of Petroleum Technology*, June 1980, pp. 968-970.

Water Compressibility (gas saturated) (psi^{-1}) **Cw(T, P, Rsw, Salt)**

Ranges of validity: 80 < T < 250°F

1,000 < P < 6,000 psia

0 ≤ Salt < 25% by weight

References:

Craft, B. C. and Hawkins, M. F., *Applied Petroleum Reservoir Engineering*, Prentice-Hall, 1959, p.130.

Meehan, D. N., "A Correlation for Water Compressibility," *Petroleum Engineer*, November, 1980, pp. 125-126.

Numbere, D., Brigham, W. E., and Standing, M. B., *Correlations for Physical Properties of Petroleum Reservoir Brines*, Petroleum Research Institute, Stanford University, November, 1977, p. 17.

Water Formation Volume Factor (gas saturated) (rb/STBW) **Bw(T, P, Salt)**

Ranges of validity: $100 < T < 250^{o}F$
$1{,}000 < P < 5{,}000$ psia
$0 \leq$ Salt $< 25\%$ by weight

References:

Craft, B. C. and Hawkins, M. F., *Applied Petroleum Reservoir Engineering*, Prentice-Hall, 1959, p.131.

Numbere, D., Brigham, W. E., and Standing, M. B., *Correlations for Physical Properties of Petroleum Reservoir Brines*, Petroleum Research Institute, Stanford University, November, 1977, p. 16.

Ramey, H. J., Stanford University, unpublished correspondence.

Water Viscosity (gas saturated) (centipoise) **Uw(T, P, Salt)**

Ranges of validity: $32 < T < 572^{o}F$
$1{,}000 < P < 3{,}200$ psia
$0 \leq$ Salt $< 25\%$ by weight

References:

Haywood, R. W., "Sixth International Conference on the Properties of Steam-Supplement on Transport Properties," *J. Eng. Power, Trans. ASME*, January, 1966, pp. 63-66.

Numbere, D., Brigham, W. E., and Standing, M. B., *Correlations for Physical Properties of Petroleum Reservoir Brines*, Petroleum Research Institute, Stanford University, November, 1977, p. 8.

Keenan, J. H., et al, *Steam Tables*, John Wiley and Sons, 1969, p.141.

Van Wylen, G. J. and Sonntag, R. E., *Fundamentals of Classical Thermodynamics*, John Wiley and Sons, 1973, pp. 40-41.